“EDS” (ADVANCED ELECTRIC DRIVE SYSTEMS FOR BUSES, VANS AND PASSENGER CARS OT REDUCE POLLUTION): AN IMPORTANT STEP TOWARDS NEW EUROPEAN DEVELOPMENTS

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ABSTRACT

The EDS report reflects the results of the 17 studies performed on different dedicated topics in different member states of the European Community. There exist clear differences between these countries but it can be stated that reports on one particular country in Europe can be extrapolated in some extent to the other countries.
The different topics handled were:
Fuel cells (B), Infrastructure (D, B), Communication networks (D), Drive systems (D, B), Social acceptance and environmental impact (D, NL), Hydrogen (B), Batteries (D), Sodium-Sulphur batteries (D), Hybrid cars (UK, F, D), Materials supply (UK), Hybrid buses (I), Electric vehicles (D).
In this communication we are presenting a short summary of important features or conclusions resulting from the reports.

MOBILITY AND EMISSIONS

There is a strong correlation between traffic and quality of environment. The Netherlands, for instance, have the highest number of vehicles per square kilometre. 75% of the trips are made by passenger cars. Without regulation, mobility by car will increase by 60% between 1986 and 2010. In other countries, an increase with 40 % is foreseen The Dutch government hope to limit this increase to 35% by way of taxes and "car-pooling" promotion, by reducing access to parking areas and by improving public transportation. Nevertheless, it seems obvious that even with state intervention, traffic will increase considerably in the next decades.

Emissions

Electric vehicles or hybrid vehicles in cities are emission-free at the point of use and therefore offer a dramatic improvement in local environmental conditions. It is important to compare the electric or hybrid vehicles with the established internal-combustion engined vehicles at the global environmental level. This comparison takes into account all emissions from primary energy mining through fuel preparation to end energy use.
The shares of the various types of primary energy in the electricity generated for any electric vehicle have to be determined for each country examined. An “European average” of pollutant emissions can be calculated for the generated kWh required for

an electric vehicle. The distribution of electricity productions between different primary energy sources is reflected in these figures. Following results are obtained:

	dust (mg/km)	SO_2 (mg/km)	NO_x (mg/km)	HC (mg/km)	CO (mg/km)	CO_2 (g/km)
petrol	15	100	880	310	2150	234
diesel	135	220	840	300	2140	214
electric	26	630	276	16	27	126

The emissions for the electric vehicle are significantly lower than for the petrol and diesel vehicles, except for sulphur dioxide, due to the use of sulphurous coal in power stations. This is likely to be reduced significantly in the future. In a common European sense the electric and hybrid vehicle is an ideal means to reduce pollution.
Traffic contribution to polluting emissions is already very high : 65% CO, 55% NOx and 45% hydrocarbon emissions. These percentages are even higher in urban areas. The number of Dutch citizens complaining from traffic noise has increased from 49% to 60% in the last few years. 19% of them experience a noise stress superior to 70 dB(A).

Annual mileage

In the European Community, the annual mileage of each car depends on the number of vehicles per family and the development of each country's economy [P-030].
This mileage ranges from 6200 km/year in Spain to 15000 km/year in Luxembourg. The average mileage for highly industrialized countries such as Germany, Great-Britain and France is about 13000 km/year.
If you consider the number of days during which a car is not used, we reach a 50 day average a year in Germany (that is to say one day per week), which corresponds to a 40 km daily mileage.
Carrying on the analysis, we can establish a correlation between annual mileage and displacement. Cars fitted with a displacement exceeding 2000 cc (15% of motor vehicles) cover an annual mileage of 18000 km. Annual mileage increases with displacement.

There is also a difference between diesel motor vehicles (18000 km/year) and petrol vehicles (13500 km/year).

The number of low displacement vehicles is much higher in large urban areas.

Daily mileage

Mobility is characterized by the number of trips per person. In Germany, mobility seems to stabilize to 2,73 trips per day and person, 1,5 of them made by car. If we correlate the latest figure to the number of owners of vehicles, we reach a number of

3,52 trips per day and vehicle.

If we analyse the length of the trips, we can note that 75% of them do not exceed 10 km and 21 % are under 2,4 km. Therefore, only 2 % of the trips exceed a length of 50 km ! It means that 98 % of the trips range between 0 and 50 km [P-030].

Similar data are given in [P-043] with slight differences but with a ventilation over six groups of annual mileages
- 3400 km/a: never exceeds 100 km/d
- 5600 km/a: exceeds 100 km/d for 7 % of trips
- 6100 km/a: never exceeds 100 km/d
- 10000 km/a: exceeds 100 km/d for 7 % of trips
- 12000 km/a: exceeds 100 km/d for 9 % of trips
- 33000 km/a: exceeds 100 km/d for 15 % of trips

For goods delivery in cities, 100 km/d are very very seldom occurring

The conclusion is obvious : the present-day car fleet is conceived for trips that only represent less than 10 % of the total number of trips (more than 100 km) or at the most 30 % (more than 10 km) of the total number of trips.

The introduction of electric and hybrid vehicles will clearly cover all the needs if economically justified. Electric vehicles can play a big role. Of course, a reduced length of the trips will be connected with a long parking period for the vehicles. Indeed, the average daily utilization only reaches 40 minutes, which corresponds to a parking average of more than 23 hours. Therefore, the time needed for recharging the batteries of electric and hybrid vehicles is more than enough and (and above all) at night, that is to say during the low load period.
The EDS study aims at analysing solutions for motor vehicles that could progressively take over nowadays technology which exclusively uses internal combustion engines.

The possible solutions necessarily must offer a considerable advantage as to their impact on environment. Furthermore, the cost of these solutions should imply a positive economic balance, particularly if we take into account the total benefit for the society as a consequence of environmental improvement.

This positive impact on environment as well as the positive global economic balance have focused the action on the solutions that allow the use of electric traction in road transport because this kind of technology makes use of an intrinsically non-polluting source of energy. However, this considerable advantage is limited by the storage capacity of electric energy on the vehicle, and by the type of power generation used, either in the vehicle, in power plants, or in decentralized power plants (solar, wind or co-generation group). It is already clear that in a near or medium term no additional power plants will be needed. This confirms the statements already formulated in the European report COST 302.

The main themes that have been chosen are the electric and hybrid vehicles, both analysed as complete transport systems according to their design. We will also focus on the components of electric and hybrid vehicles because they often imply the use of highly advanced and developing technologies.

The infrastructures needed for electric and hybrid vehicles are also described where applicable.

EVALUATION OF DEVELOPMENT TRENDS AND OBSTACLES

The present-day car fleet is conceived for trips that only represent less than 10 % of the total number of trips (more than 100 km) or at the most 30 % (more than 10 km) of the total number of trips.
First, we should make a fundamental comment: the internal combustion engine vehicle is still progressing towards reducing fuel consumption (therefore primary energy consumption) and meeting lower emission standards but it has already reached a high degree of maturity thanks to a hundred years of efforts devoted to its development; on the contrary, electric and hybrid vehicle technology is not much developed particularly its propulsion system and the energy source.

The electric vehicle

Three phases can be discerned in the development of the electric vehicle.

The current situation proves that the electric vehicle can already be built and used for particular applications, either from the point of specific targeted missions given from the point of energy sources to be used.

A development methodology for optimization of technology is necessary to carry out the industrialization of a reliable product for specific applications. This process has hardly been started. Consequently, considerable efforts in development are necessary; they should be based on the realization of experimental pre-industrialized fleets of satisfactory size.

Despite the current advancement in technology, coordinate development is still very necessary in order to meet the goal of standardization. Evaluation of different solutions and design hypotheses could usefully be performed by means of a simulation tool with sufficient universality, to be used by different R&D centres and to be able to accept easily, through a modular structure, the introduction of new elements.

Fundamental research remains an important element in the development of electric vehicles in the long term as in every industrial field. In this case, it is of utmost importance since the electric vehicle technology still is in the initial stage of its

development.
These efforts in fundamental research should focus on structures, electric motors, electronic components of static converters and batteries.
An important effort in standardization is indispensable for the components of electric vehicles but mainly for batteries.

The hybrid vehicle

It is clear that the hybrid solution is a serious alternative to the current vehicle fleet as to its energy and environmental consequences. It is also obvious that a considerable effort in development is necessary in order to determine the most appropriate solutions.

The hybrid electric bus

This solution should be proved further with the development of an experimental fleet of about twenty vehicles exploited in an urban area, which would make it possible to draw the lessons that can be expected from a pre-production and initial commercialisation phase.

At the same time, research efforts should be achieved in order to implement other types of generating groups such as fuel cells, Stirling motor, gas turbine etc.

Batteries

The industrial design and the development of traction batteries must clearly be pursued because it has already be demonstrated that some types are really technically and economically to be considered. In a short and medium term, it appears that following batteries have a serious chance to find their application in electric vehicles: lead-acid, sodium-sulphur, nickel-cadmium, sodium-nickel chloride, zinc-bromine.

Fuel cells

The conclusions resulting from the analysis of the fuel cell stage of development are the following ones :
At present, there are three types of fuel cells. By developing them for their application on road vehicles, fuel cells could give concrete results in the medium term. These are

- the AFC alkaline fuel cell
- the PAFC phosphoric acid fuel cell
- the PEFMC proton exchange membrane fuel cell

The direct combustion of methanol to produce fuel cell hydrogen requires the application of a "reformer"; this process eliminates the application of the alkaline solution
At the present stage of development of these fuel cells, a demonstration on a certain number of vehicles is very important. This demonstration should be followed by a pre-industrialization phase on a sufficient fleet of vehicles.

Electric motors

Electric motor technology is well developed but it mainly appears under the form needed for standard industrial applications.
The association of electric motors with power electronics has led to a fundamental evolution in technology. Above all, it has allowed the most recent developments in electric transportation (tram, trolleybus, and automatic systems).
The technology required for electric vehicles is fundamentally the same but it differs considerably as to its application. Indeed, it is necessary to achieve important developments that would be adapted to the specific needs of road vehicles, including their economical and cost-effectiveness aspects and environmental benefits.
Consequently, a significant technological effort must be accomplished.

Electric and hybrid vehicle electronics

It is urgent to recognize the role of power electronics in its whole industry and agree to make the research and development efforts needed for holding up its present-day position in this field. These efforts take place in a fundamental prospect of rational management and reduced consumption of electric energy.
It is obvious that these efforts will benefit to the motor car as well as to the electric and hybrid vehicle industries.
They will have to take place in the field of components and structures and will also concern the integration of intelligent to power functions.
The whole structures and functions needed for electric vehicles exist at the industrial level but are not adapted to road traction. The technological transfer leads to solutions that are not adapted to their functions and not very reliable.
Power components are responsible for transforming energy on the vehicles. Therefore, they have a high efficiency and specialized components for electric and hybrid vehicles should be developed.
The control and command functions are essential. They will be partially or totally integrated to power functions. Since they have a central role, they will require considerable development efforts.

Internal combustion engines

The usable solutions could be provided by the work carried out in the framework of development efforts in the "clean" car technology. Hybrid structures, called "parallel" structures, leave part of the traction function to internal combustion engines; this function is similar to that of a traditional vehicle. In this case, the technological transfer is obvious.
Hybrid solutions will have to be the subject of thorough investigation in order to define the best solutions. This could be carried out with a simulation software tool, with sufficient universality and modularity to make an easy comparison of the different structures.
From this preliminary stage, a demonstration phase on several vehicles will make it

possible to compare the different solutions. Eventually, the pre-industrialized fleets will be implemented in a preparation phase aiming at elaborating proposals for the market.

Infrastructure and electricity distribution problems

The conclusions of the study on infrastructure and electric energy needs are the following ones :

- in the short term (5 years), there is no problem to be expected for the electricity distribution infrastructure;
- in the medium term (5-10 years) the appearance of problems (local overload) is possible but not dramatic
- in the case of massive introduction of electric vehicles (long term), for cost-effective reasons, it is probably necessary to introduce centralized or decentralized management systems of the electric energy that can be distributed;
- electric charging facilities in public areas will have to be analysed by standardization on an international level;
- the whole parking infrastructures are to be studied again in order to be accessible for electric vehicles;
- studies on the impact on the distribution network will be necessary in every city;
- at the level of electricity generation no dramatic problems are to be foreseen
- rent-a-car systems can be introduced and use the distribution network as a support for management and control data transmission.

In order to define city infrastructures described above, the following actions could be progressively adopted :

- organizing demonstration fleets in several cities; these fleets would be concentrated in limited areas in order to analyse the infrastructural impacts (we must avoid to mitigate effects);
- determine more important setting-up zones with a sufficient percentage of vehicles (10 to 20 %);
- study the impact in different cities of an increasing percentage of electric vehicles.

ELECTRIC VEHICLE ACCEPTANCE BY USERS

The penetration potential of electric vehicles is high but measures have to be taken in order to convince and stimulate people to purchase electric vehicles according to their attractiveness.

A thorough effort will be necessary as well as an increased number of examples initiated by the authorities. These should consider promoting electric and hybrid vehicle penetration by way of :

- tax measures
- regulation actions
- creating preferential access areas
- lowering noise emission levels.

TRAFFIC MANAGEMENT ACTIONS AND INFRASTRUCTURE DESIGN

We can assess that the role of electric vehicles in urban organization mainly depends on the improvement of this organization and not only on the introduction of such vehicles.
As far as hybrid vehicles are concerned, the viewpoint is the same as to their impact on road transportation as a whole.
There are several means to initiate the penetration movement of electric and hybrid vehicles :
- implementing bus and minibus fleets
- use by public services
- electrifying the fleet used by the Commission
- testing out rent-a-car systems in several cities
- implementing electric and hybrid taxis.

FACTORS OF DEVELOPMENT

The electrotechnical industry that will conceive the electric drive system and control system; it is important to underline the urgent necessity in recognizing the quality of fundamental technology in the power electronics field and to define research and development programs for it in order to reinforce competitiveness at a world-wide level;

REGULATION FAVOURING ELECTRIC AND HYBRID VEHICLE DEVELOPMENT

The implementation of the Clean Air Act in Los Angeles and South California is the reference point and everybody will expect the results with great interest.

PRIORITY RTD ACTIONS

Electric vehicles prove to be important as a means to reduce pollution, due to their typical urban operation theatre.
Hybrid vehicles combine the advantage of electric vehicles in the cities and of extension of range for the part of the displacements (20 to 30 %) being longer than 100 km.
They are offering an interesting substitution possibility in the field of energy saving, at least demonstrated in most cases.
Electric and hybrid vehicles and their components are still in a pre-production and initial commercialisation phase.
In this respect we suggest action priorities in the following fields could be suggested:

In the technical field:

- The development of pre-industrialized and pre-marketed fleets based on existing technologies. This need to occur on a satisfactory scale to create an useful feedback for future developments.
  Pilot development of fleets allows the same development of the corresponding components: motors, electronic converters, control electronics and energy sources.
- The short-term and medium-term existing energy sources (Pb-acid, Ni-Cd, Na-S, Na-NiCl, Zn-Br) should be further developed. The pilot plant stage is connected with the pre-marketing of the fleet. The preparation of the step towards full industrialization has a strong impact on the economy of electric and hybrid vehicles.
- The electric systems (electric and hybrid vehicles) and thermal systems (hybrid vehicles) have to undergo the technological evolutions needed for the use on board of vehicles. This is the responsibility of the corresponding industry in strong collaboration with the automotive industry.
- University and research centres should intensify their role in preparing the way for new components; the development of simulation software to evaluate the merit of different solutions would be a very useful tool if sufficiently general, modular, interactive and widespread.

In the legal and educational field

- Standardization efforts will have the advantage to promote coordination between development efforts; they should not be too restrictive in first instance.
- Actions to demonstrate the advantage and characteristics of electric and hybrid vehicles to the users and the public authorities should be developed; a good knowledge of these new technologies will have a double aspect:
  - helping the public authorities to take the measures allowing to meet their goals with respect to pollution, energy and traffic regulation;
- preparing the users for the new coming market and to accept the new regulations.

LIST OF EDS SUBCONTRACTORS

Nr.	Participant	Title
P-001	ELENCO, Dessel, Belgium	Piles à combustible (Fuel Cells)
P-002	Technische Universität, Berlin, Germany	Concepts and models for the introduction of battery charging stations for electric vehicles in centres of big cities
P-003	Univ. Kaiserslautern, Germany	Decentralizing of electric vehicle components by a communication network
P-004	Université Libre de Bruxelles, Brussels, Belgium	Elaboration de stratégies de commande adaptées aux véhicules électriques mus par moteurs à courant alternatif
P-005	Studiengesellschaft für Nahverkehr, Hamburg, Germany	Evaluation of advanced electric drive systems for buses, vans and passenger cars concerning their environmental benefits
P-016	Hydrogen Systems, St. Truiden, Belgium	Technical and economical comparison between a conventional trolleybus system and a bus system based on electrolytic hydrogen
P-017	Energiestudiecentrum Nederland, Petten, The Netherlands	Urban electric transportation systems. Social Acceptance and impacts on environment and electricity production
P-018	Vrije Universiteit Brussel, Brussels, Belgium	Analysis of distribution, training and information infrastructures required for the use of electric and hybrid vehicles in town traffic
P-021	ABB Hochenergiebatterie, Heidelberg Germany	Application of "The Smart Battery Drive System" for electric road vehicles
P-022	ABB Hochenergiebatterie, Heidelberg, Germany	Application of NaS high energy batteries for road vehicles
P-027	PSA, Paris, France	Voiture Particulière Electrique Hybride

P-028	Electric Vehicle Development Group, Richmond, Surrey, England	The environmental impact of electric vehicles, covering materials supply, air pollution, electromagnetic interference, noise and safety factors, related to cost benefits for Europe as a whole
P-030	Institut für Kraftfahrwesen, Rheinisch-Westfälische Technische Hochschule, Aachen, Germany	Analysis of hybrid-drive systems with new electric components and optimization of one concept morphology evaluation and optimization
P-033	Genova Ricerche, Genova, Italy	Low emission urban hybrid vehicle
P-036	The University of Birmingham, Automotive Engineering Centre, Birmingham, England	Analysis of design and operation of environmentally friendly battery and hybrid powered cars, vans and small general purpose vehicles
P-039	PTI Albatech, Trofarello, Italy	Hybrid bus with wheel hub motor
P-043	Daimler-Benz, Stuttgart, Germany	Elektrofahrzeuge mit Batterien und ihr Einfluß auf die Umwelt
P-044	Institut für Stromrichtertechnik, Rheinisch-Westfälische Technische Hochschule, Aachen, Germany	Comparison and evaluation of nickel-cadmium, zinc-bromine, sodium-sulphur and lead-acid batteries